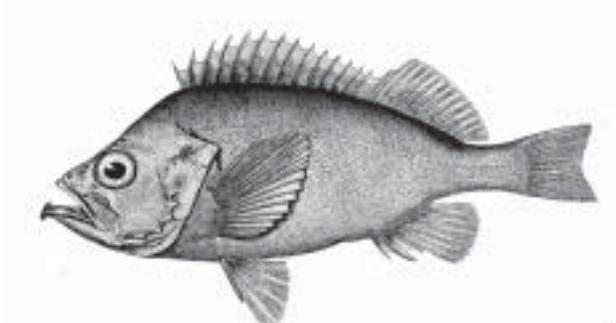
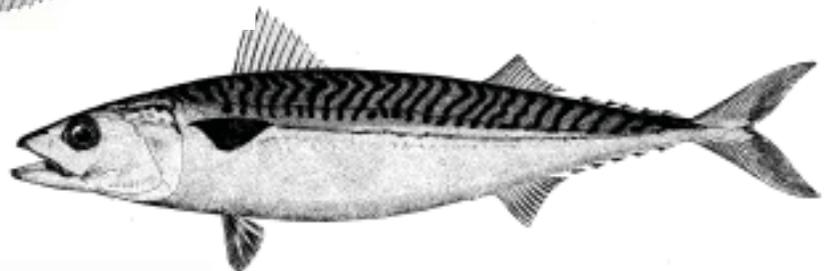
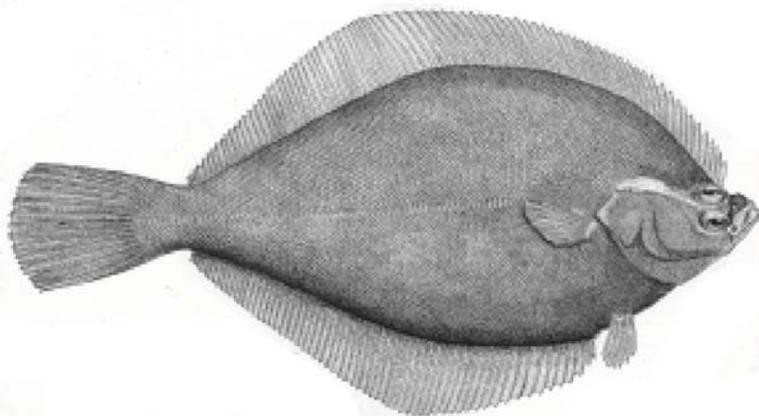




Accuracy and Precision Exercises Associated with 2006 TRAC Production Aging

by Sandra J. Sutherland, Nina L. Shepherd, Sarah E. Pregracke, and John M. Burnett



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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts

January 2007

Northeast Fisheries Science Center Reference Documents

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This document's publication history is as follows: manuscript submitted for review December 6, 2006; manuscript accepted through technical review December 6, 2006; manuscript accepted through policy review December 6, 2006; and final copy submitted for publication January 10, 2007. This document may be cited as:

Sutherland SJ, Shepherd NL, Pregracke SE, Burnett JM. 2007. Accuracy and precision exercises with 2006 TRAC production aging. U.S. Dep. Commer., *Northeast Fish. Sci. Cent. Ref. Doc.* 07-01; 20 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026.

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Introduction

In production aging programs, age reader accuracy can be thought of as how often the “right” age is obtained, and precision as how often the “same” age is obtained (Campana 2001). It is possible that, over time, an age reader may inadvertently change the criteria that are used for determining ages, thereby introducing a bias into the age data. This bias can be measured with accuracy tests, which consist of the age reader blindly examining known- or consensus-aged fish from established reference collections. An age reader may also make periodic mistakes, which introduces random errors into the data. The degree of this error can be measured with precision tests, which consist of the age reader blindly re-aging fish which they have already aged. Both accuracy and precision must be considered within a quality-control monitoring program.

Acceptable levels of aging accuracy and precision are influenced by factors such as species, age structure, and age reader experience. Although percent agreement is strongly affected by these differences, the staff of the Fishery Biology Program at the Northeast Fisheries Science Center (NEFSC) have long considered levels above 80% to be acceptable. The total coefficient of variation (CV) is less affected by these differences and, thus, is a better measure of aging error. In many aging labs around the world, total CVs of under 5% are considered acceptable among species of moderate longevity and aging complexity (Campana 2001), such as the species considered here.

For over 35 years, scientists at the NEFSC Fishery Biology Program have regularly conducted production aging, determining the ages for large numbers of samples over a short period of time using established methods (Penttila and Dery 1988), for the species assessed by the Transboundary Resources Assessment Committee (TRAC). Historically, our approach to age-data quality control and assurance has been a two-reader system. In this approach, there are both a primary and a secondary age reader for each species. The primary age reader conducts all production aging, and the secondary age reader then ages a portion of those same samples using similar methods. The ages determined by the two readers are compared, and if they agree sufficiently (above 80% agreement), the production ages are considered valid. If not, the sources of disagreement must first be resolved. This interreader approach is still used in the course of training new readers in order to ensure consistency in application of aging criteria and in inter-laboratory sample exchanges. Budgetary and staffing constraints have made this approach less feasible, however, by reducing the number of species for which there are two competent age readers at this laboratory.

In the past few years, the NEFSC Fishery Biology Program has updated our approach to quality control and assurance. Intrareader tests of aging accuracy and precision, as described above, allow us to quantify the amount of inherent aging error and bias in the ages determined by each of our staff members. These values provide a measure of the reliability of the production age data used in stock assessments, and they may be directly incorporated into population models as a source of variability.

In conjunction with implementation of these tests, we have begun to establish reference collections of age samples for each species. These collections are necessary to evaluate aging accuracy. Fish of known age are difficult to obtain, so we have focused on assembling collections from age samples which have been included in aging exchanges with other laboratories. From those samples, we have selected those fish for which multiple experienced age readers agree on the age (see Silva et al. 2004 for more details).

As in past years, exercises were undertaken to estimate the accuracy and/or precision of U.S. production aging for the 2006 TRAC assessments (Legault et al. 2006; Gavaris et al. 2006; Van Eeckhaute and Brodziak [in press]) of Georges Bank stocks of cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), and yellowtail flounder (*Limanda ferruginea*). This report lists the results of those exercises.

Methods

In all cases, the primary age reader for each species conducted the production aging and completed all accuracy and precision exercises. Subsamples were randomly selected to be re-aged in order to test age-reader accuracy (versus the reference collections) or precision (versus samples previously aged by that reader). When re-aging fish, the age reader had knowledge of the same data as during production aging (i.e. fish length, date captured, and area captured) but no knowledge of previous age estimates. During age-testing exercises, no attempts were made to improve results with repeated readings. There was also no attempt to revise the production ages in cases where differences occurred.

Results are presented in terms of percentage agreement, total coefficient of variation (CV), age-bias plots, and age-frequency tables (Campana et al. 1995; Campana 2001). In the precision exercises, a Bowker's test (Bowker 1948; Hoenig et al. 1995) was also used to test for deviations from symmetry in any case where the percent agreement fell below 90%. This test can be used to objectively detect a strong bias when comparing two sets of ages.

Age-reader accuracy was determined for both cod and haddock, from a random subsample drawn from the corresponding NEFSC otolith reference collection. For cod, this exercise was done after the completion of production aging. For haddock, exercises were completed both before and after production aging. Accuracy for yellowtail flounder aging was not assessed at present, because the reference collection for that species is not yet complete.

For all three species, age-reader precision was estimated from blind second readings of subsamples from each NEFSC survey (autumn 2005 and spring 2006). Similar precision tests were conducted for samples from the 2005 NEFSC commercial port samples, but the haddock samples were further broken down by commercial quarter.

Results and Discussion

The total sample sizes associated with the accuracy and precision exercises were $N = 225$, 483, and 183 for cod, haddock, and yellowtail flounder, respectively. Results for cod are presented in Figures 1–4, haddock in Figures 5–12, and yellowtail flounder in Figures 13–15. Results of the three accuracy tests are summarized in Table 1, while all precision exercise results are shown in Table 2. The Bowker's test was run for three of the haddock precision exercises and two of the exercises for yellowtail flounder; in no case did this test reveal a significant deviation from symmetry (Table 2).

For cod, the accuracy estimate was high (87% agreement), and the total CV (3.9%) was low. There was a mild tendency toward overaging (Figure 1). This accuracy has dropped slightly from last year (91% agreement and 1.5% CV, Sutherland et al. 2006), when another age reader conducted the production aging. Cod precision levels were high, ranging from 94 to 98%

agreement and from 0.2 to 1.2% CV (Figures 2–4). No bias was apparent in these exercises. Both the high accuracy and precision levels indicate that the cod age reader has maintained a reliable level of aging capability.

For haddock, both accuracy estimates were high (96 and 92% agreement, total CVs of 1.0 and 1.1%, Figures 5 and 6), indicating that the application of aging criteria has not changed in the past year. Precision levels were between 85–97% agreement and 0.6–2.2% CV (Figures 7–12), indicating that age determinations were consistent. No bias was apparent in any of these exercises. Although this year's results are lower than those in 2005 (median of 95% agreement and 0.7% CV, Sutherland et al. 2006), these precision levels are well within accepted limits. The high accuracy estimates and consistently high precision results indicate that the haddock age reader is continuing to provide reliable ages.

Precision levels for yellowtail flounder were between 82–90% agreement and 1.6–5.1% CV (Figures 13–15). In no case was the difference between the production and test ages greater than one year. There may have been a weak bias toward underaging during the precision exercise on autumn survey samples, but this was not found to be significant ($P < 0.05$, Bowker's test). Overall, these precision levels are higher than they were last year, when the current age reader was still in training (73% agreement and 6.1% CV for U.S. samples, Sutherland et al. 2006). These high precision levels, combined with an increase since last year, indicate that the new age reader has attained a reliable level of aging capability.

Among these three species, U.S. precision measures did not fall below acceptable in-house precision or accuracy levels in the past year's production aging. In most cases, these levels were exceeded. Therefore, U.S. age determinations are considered to be reliable during recent production aging.

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* Available at <http://www.mar.dfo-mpo.gc.ca/science/trac/trac.html>

Table 1. Results of accuracy exercises using the NEFSC reference collections. Figure numbers indicate the corresponding figures in this report. Initials for each age reader are given; the primary age reader for each species conducted the tests in all cases.

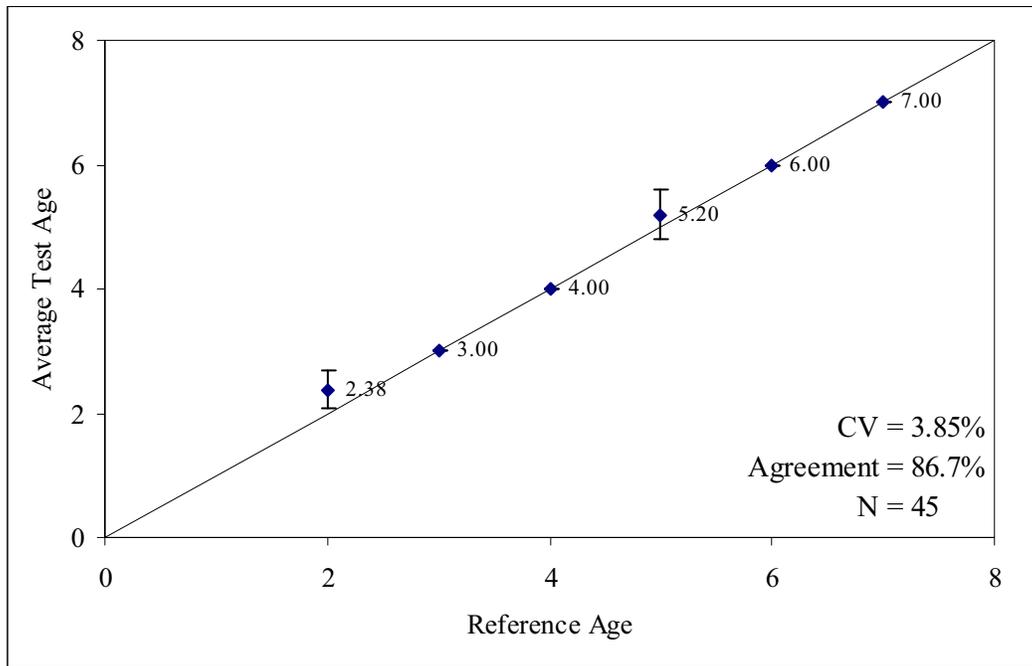
Figure	Age Reader	Species	Test Date	N	Total CV (%)	Agreement (%)
1	NS	Cod	May 2006	45	3.85	86.7
5	SS	Haddock	Jan. 2006	55	1.03	96.4
6	SS	Haddock	May 2006	51	1.12	92.2

Table 2. Results of all precision exercises. Figure numbers indicate the corresponding figures in this report. Initials for each age reader are given; the primary age reader for each species conducted the exercises in all cases. Bowker's test results either show the *P*-value, N/S (not significant at the $\alpha = 0.05$ level), or are left blank where the test was not applicable.

Figure	Age Reader	Source	Test Date	N	Total CV (%)	Agreement (%)	Bowker's Test
<u>Cod (<i>Gadus morhua</i>)</u>							
2	NS	2005 Autumn Survey	May 2006	50	0.22	98.0	
3	NS	2006 Spring Survey	May 2006	50	0.19	98.0	
4	NS	2005 Port Samples Qtr. 1-4	May 2006	80	1.20	93.8	
<u>Haddock (<i>Melanogrammus aeglefinus</i>)</u>							
7	SS	2005 Autumn Survey	Jan. 2006	100	1.25	95.0	
8	SS	2006 Spring Survey	May 2006	64	0.63	96.9	
9	SS	2005 Port Samples Qtr. 1	Feb. 2006	55	1.47	85.5	N/S
10	SS	2005 Port Samples Qtr. 2	March 2006	53	2.24	84.9	N/S
11	SS	2005 Port Samples Qtr. 3	March 2006	55	1.82	90.9	
12	SS	2005 Port Samples Qtr. 4	March 2006	50	1.44	88.0	N/S
<u>Yellowtail Flounder (<i>Limanda ferruginea</i>)</u>							
13	SP	2005 Autumn Survey	March 2006	54	5.05	81.5	N/S
14	SP	2006 Spring Survey	May 2006	50	1.56	90.0	
15	SP	2005 Port Samples Qtr. 1-4	May 2006	79	2.48	87.3	N/S

Figure 1. Results of cod age-reader accuracy exercise against randomly selected samples from the NEFSC cod reference collection. (A) Age-bias plot, showing the average age attained during the exercise for fish of each age from the reference collection. Error bars indicate 95% confidence intervals. (B) Age-frequency table, showing the ages attained during the test exercise across the top and the reference ages on the left. Numbers in the shaded boxes indicate agreement between the two ages. Numbers above this diagonal indicate fish which were over-aged during the exercise; those below the shaded boxes were under-aged during the exercise. Total age frequencies are given by age for both the test and reference ages.

A.

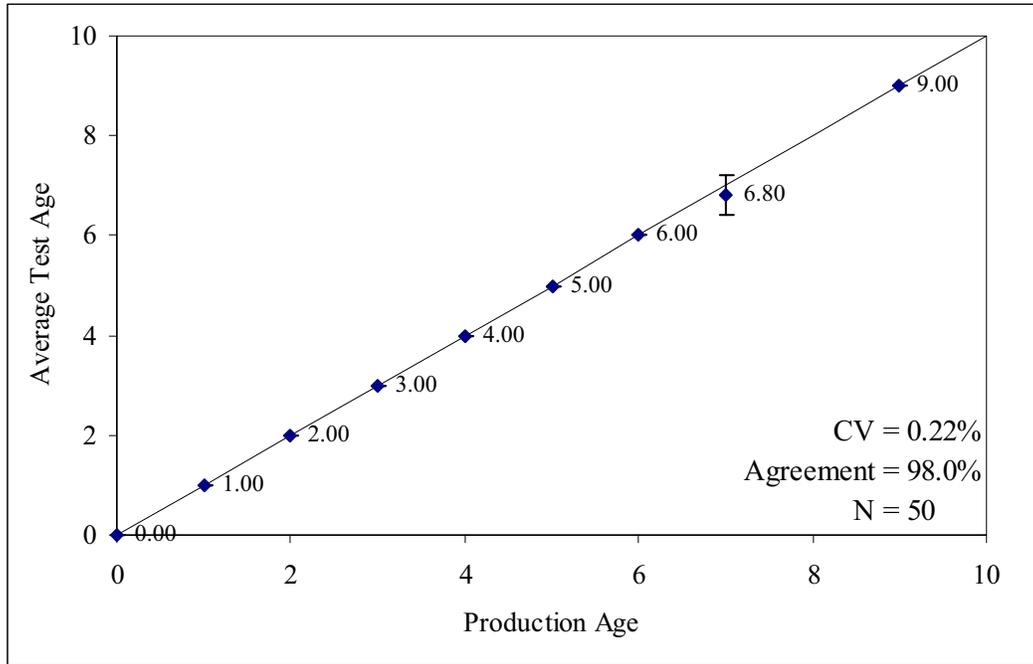


B.

Ref. Age	Test Age									Total
	0	1	2	3	4	5	6	7	8	
0	1									1
1		1								1
2			11	4	1					16
3				11						11
4					8					8
5						4	1			5
6							4			4
7								1		1
8									1	1
Total			11	15	9	4	5	1		45

Figure 2. Results of cod age-reader precision exercise against randomly selected samples from the 2005 NEFSC autumn bottom trawl survey. (A) Age-bias plot, showing the average age attained during the exercise for fish of each age as determined during production aging. Error bars indicate 95% confidence intervals. (B) Age-frequency table, showing the ages attained during the test exercise across the top and the production ages on the left. Numbers in the shaded boxes indicate agreement between the two ages. Numbers above this diagonal indicate fish which were over-aged during the exercise; those below the shaded boxes were under-aged during the exercise. Total age frequencies are given by age for both the test and production ages.

A.

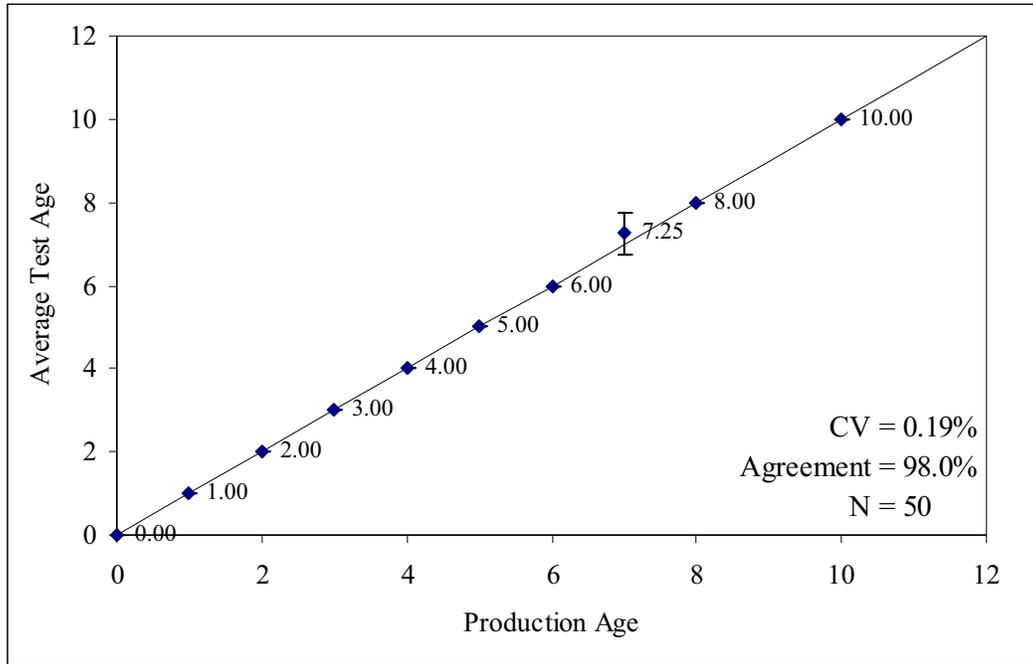


B.

Prod. Age	Test Age											Total	
	0	1	2	3	4	5	6	7	8	9	10		
0	2												2
1		4											4
2			8										8
3				12									12
4					10								10
5						2							2
6							6						6
7								1	4				5
8										1			1
9											1		1
10												1	1
Total	2	4	8	12	10	2	7	4		1			50

Figure 3. Results of cod age-reader precision exercise against randomly selected samples from the 2006 NEFSC spring bottom trawl survey. (A) Age-bias plot, showing the average age attained during the exercise for fish of each age as determined during production aging. Error bars indicate 95% confidence intervals. (B) Age-frequency table, showing the ages attained during the test exercise across the top and the production ages on the left. Numbers in the shaded boxes indicate agreement between the two ages. Numbers above this diagonal indicate fish which were over-aged during the exercise; those below the shaded boxes were under-aged during the exercise. Total age frequencies are given by age for both the test and production ages.

A.

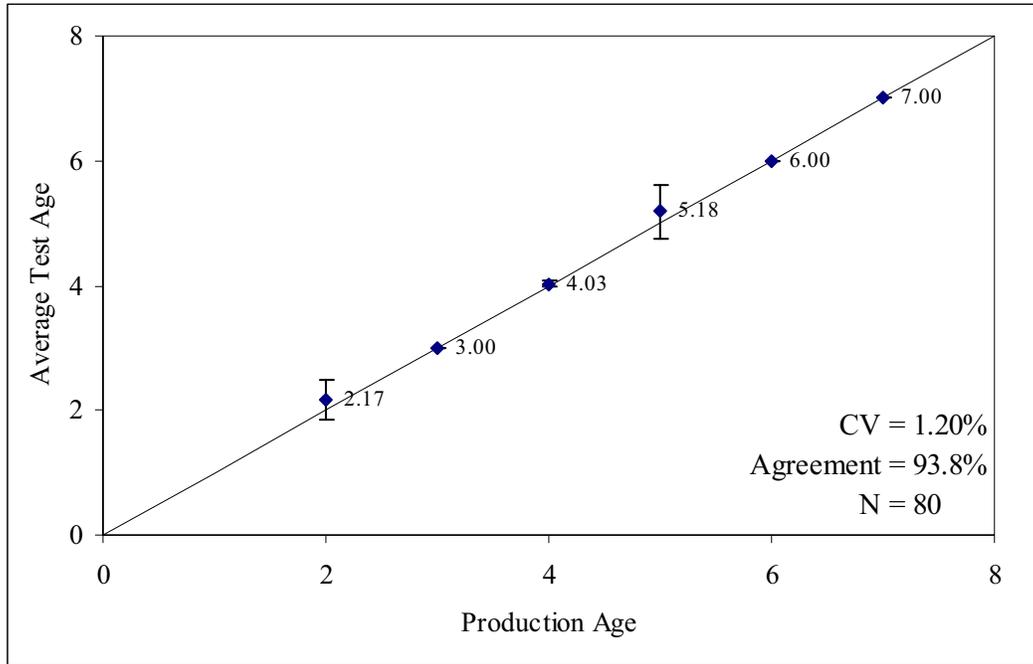


B.

Prod. Age	Test Age											Total	
	0	1	2	3	4	5	6	7	8	9	10		11
0	2												2
1		5											5
2			5										5
3				12									12
4					6								6
5						9							9
6							2						2
7								3	1				4
8									4				4
9										1			1
10											1		1
11												1	1
Total	2	5	5	12	6	9	2	3	5		1		50

Figure 4. Results of cod age-reader precision exercise against randomly selected samples from the 2005 NEFSC commercial port samples (all quarters). (A) Age-bias plot, showing the average age attained during the exercise for fish of each age as determined during production aging. Error bars indicate 95% confidence intervals. (B) Age-frequency table, showing the ages attained during the test exercise across the top and the production ages on the left. Numbers in the shaded boxes indicate agreement between the two ages. Numbers above this diagonal indicate fish which were over-aged during the exercise; those below the shaded boxes were under-aged during the exercise. Total age frequencies are given by age for both the test and production ages.

A.



B.

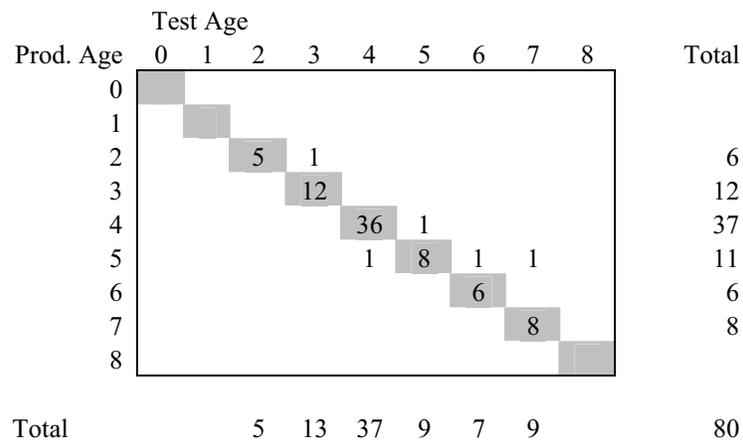
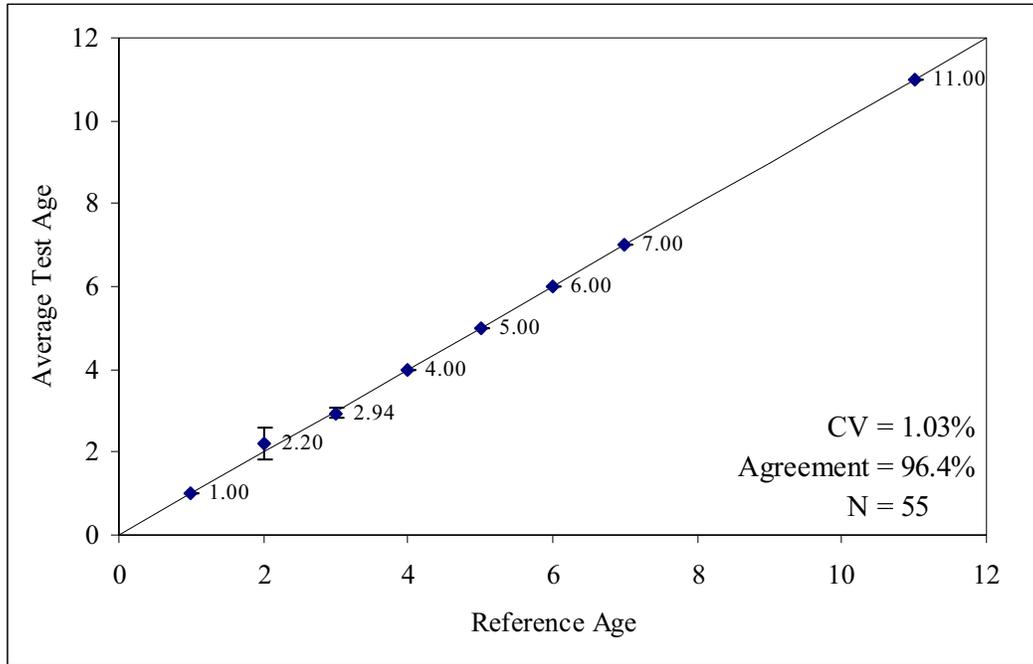


Figure 5. Results of haddock age-reader accuracy exercise against randomly selected samples from the NEFSC haddock reference collection, conducted before production aging. (A) Age-bias plot, showing the average age attained during the exercise for fish of each age from the reference collection. Error bars indicate 95% confidence intervals. (B) Age-frequency table, showing the ages attained during the test exercise across the top and the reference ages on the left. Numbers in the shaded boxes indicate agreement between the two ages. Numbers above this diagonal indicate fish which were over-aged during the exercise; those below the shaded boxes were under-aged during the exercise. Total age frequencies are given by age for both the test and reference ages.

A.



B.

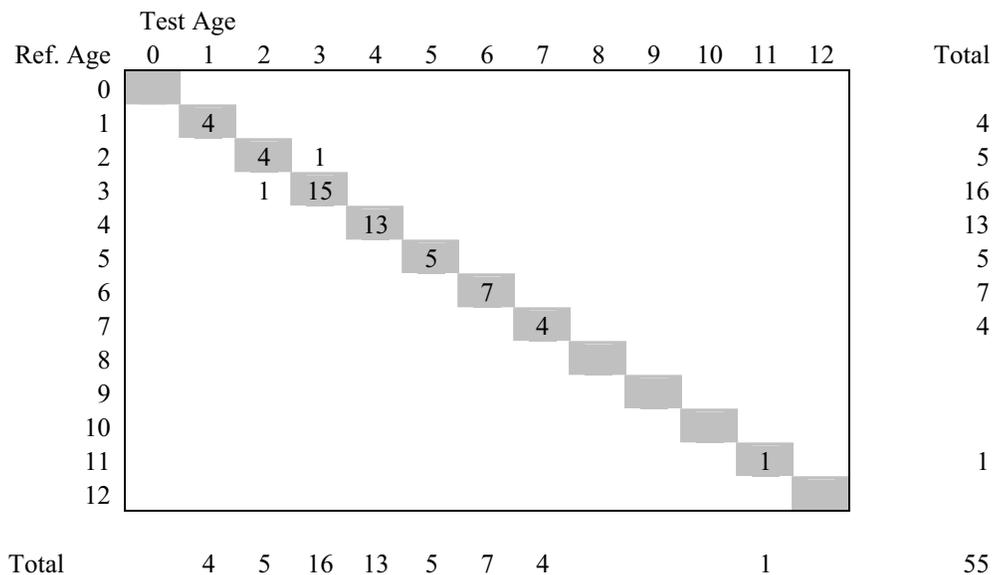
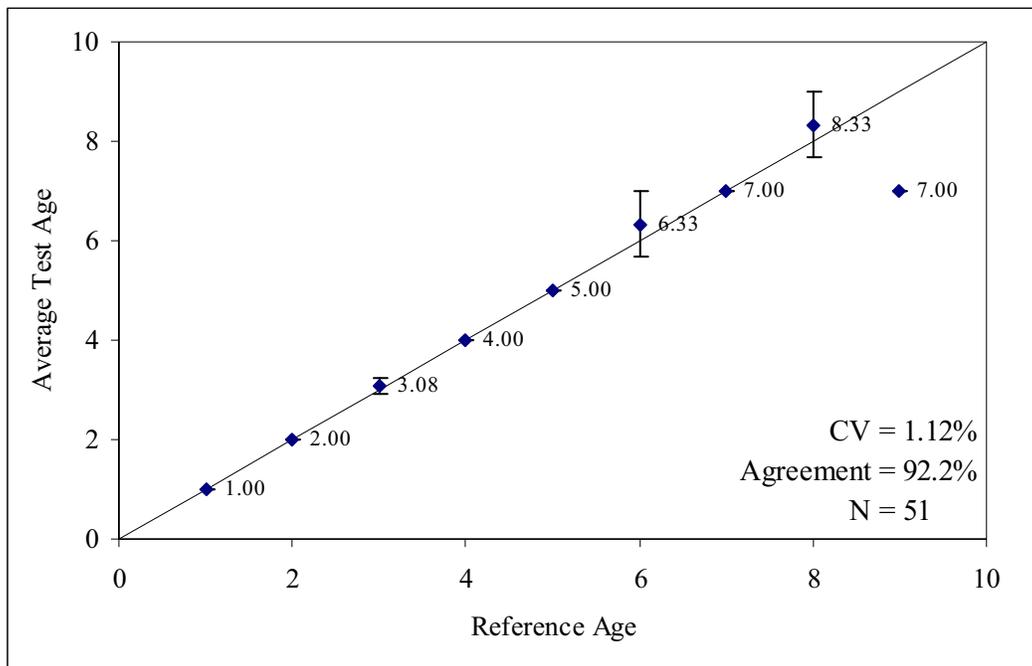


Figure 6. Results of haddock age-reader accuracy exercise against randomly selected samples from the NEFSC haddock reference collection, conducted after production aging. (A) Age-bias plot, showing the average age attained during the exercise for fish of each age from the reference collection. Error bars indicate 95% confidence intervals. (B) Age-frequency table, showing the ages attained during the test exercise across the top and the reference ages on the left. Numbers in the shaded boxes indicate agreement between the two ages. Numbers above this diagonal indicate fish which were over-aged during the exercise; those below the shaded boxes were under-aged during the exercise. Total age frequencies are given by age for both the test and reference ages.

A.

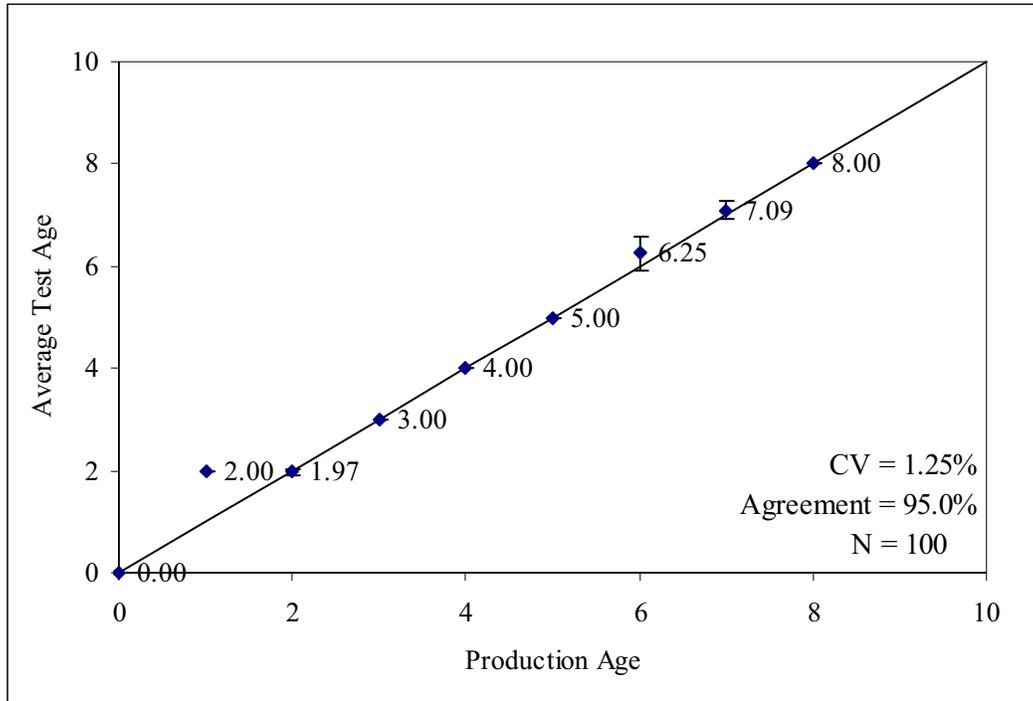


B.

Ref. Age	Test Age											Total
	0	1	2	3	4	5	6	7	8	9	10	
0	1											1
1		2										2
2			5									5
3				12	1							13
4					16							16
5						7						7
6							2	1				3
7								1				1
8									2	1		3
9										1		1
10											1	1
Total		2	5	12	17	7	2	3	2	1		51

Figure 7. Results of haddock age-reader precision exercise against randomly selected samples from the 2005 NEFSC autumn bottom trawl survey. (A) Age-bias plot, showing the average age attained during the exercise for fish of each age as determined during production aging. Error bars indicate 95% confidence intervals. (B) Age-frequency table, showing the ages attained during the test exercise across the top and the production ages on the left. Numbers in the shaded boxes indicate agreement between the two ages. Numbers above this diagonal indicate fish which were over-aged during the exercise; those below the shaded boxes were under-aged during the exercise. Total age frequencies are given by age for both the test and production ages.

A.

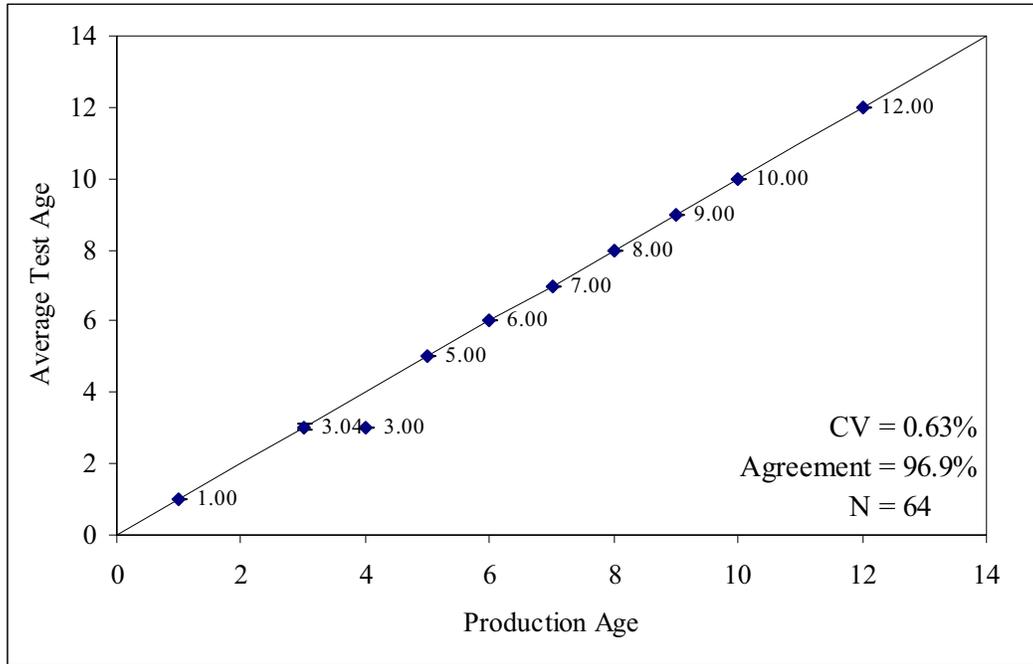


B.

Prod. Age	Test Age										Total	
	0	1	2	3	4	5	6	7	8	9		
0	10											10
1			1									1
2		1	38									39
3				2								2
4					1							1
5						25						25
6							6	2				8
7								10	1			11
8									3			3
9												
Total	10	1	39	2	1	25	6	12	4			100

Figure 8. Results of haddock age-reader precision exercise against randomly selected samples from the 2006 NEFSC spring bottom trawl survey. (A) Age-bias plot, showing the average age attained during the exercise for fish of each age as determined during production aging. Error bars indicate 95% confidence intervals. (B) Age-frequency table, showing the ages attained during the test exercise across the top and the production ages on the left. Numbers in the shaded boxes indicate agreement between the two ages. Numbers above this diagonal indicate fish which were over-aged during the exercise; those below the shaded boxes were under-aged during the exercise. Total age frequencies are given by age for both the test and production ages.

A.



B.

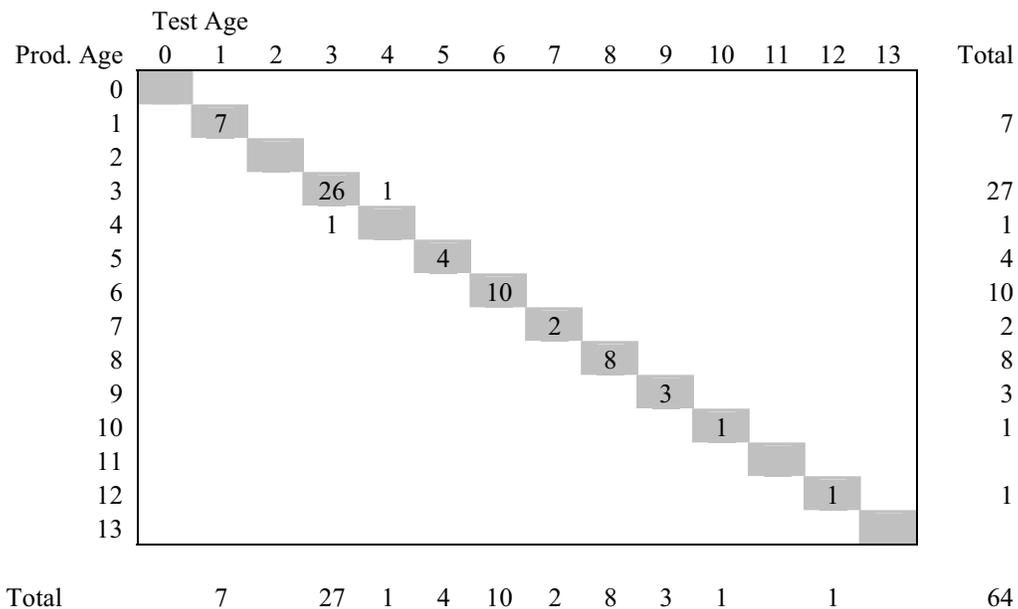
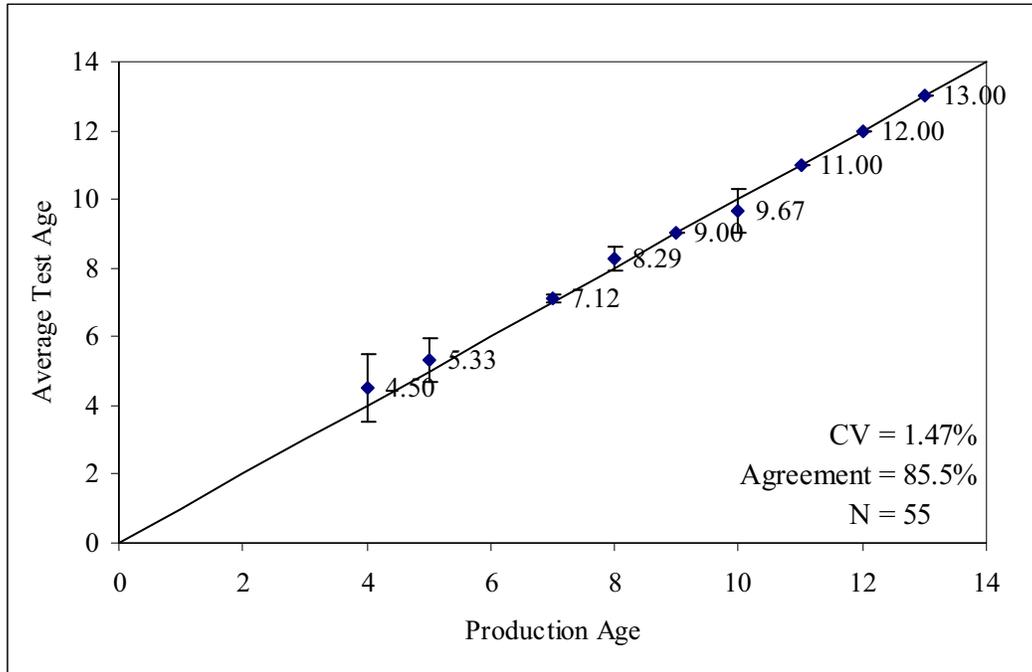


Figure 9. Results of haddock age-reader precision exercise against randomly selected samples from the 2005 NEFSC commercial port samples (1st quarter). (A) Age-bias plot, showing the average age attained during the exercise for fish of each age as determined during production aging. Error bars indicate 95% confidence intervals. (B) Age-frequency table, showing the ages attained during the test exercise across the top and the production ages on the left. Numbers in the shaded boxes indicate agreement between the two ages. Numbers above this diagonal indicate fish which were over-aged during the exercise; those below the shaded boxes were under-aged during the exercise. Total age frequencies are given by age for both the test and production ages.

A.



B.

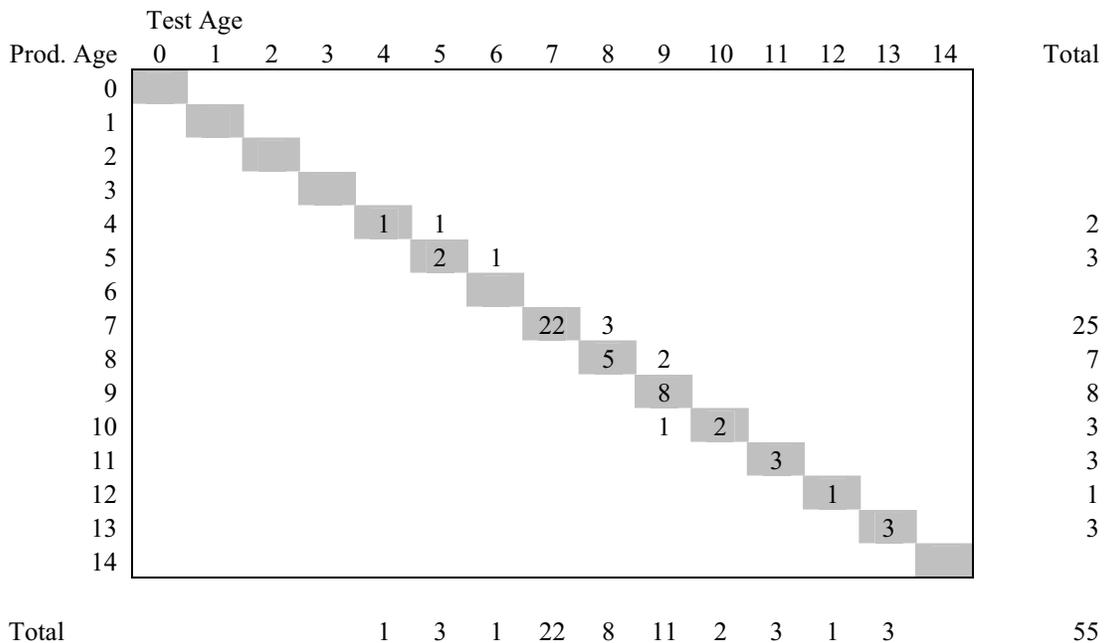
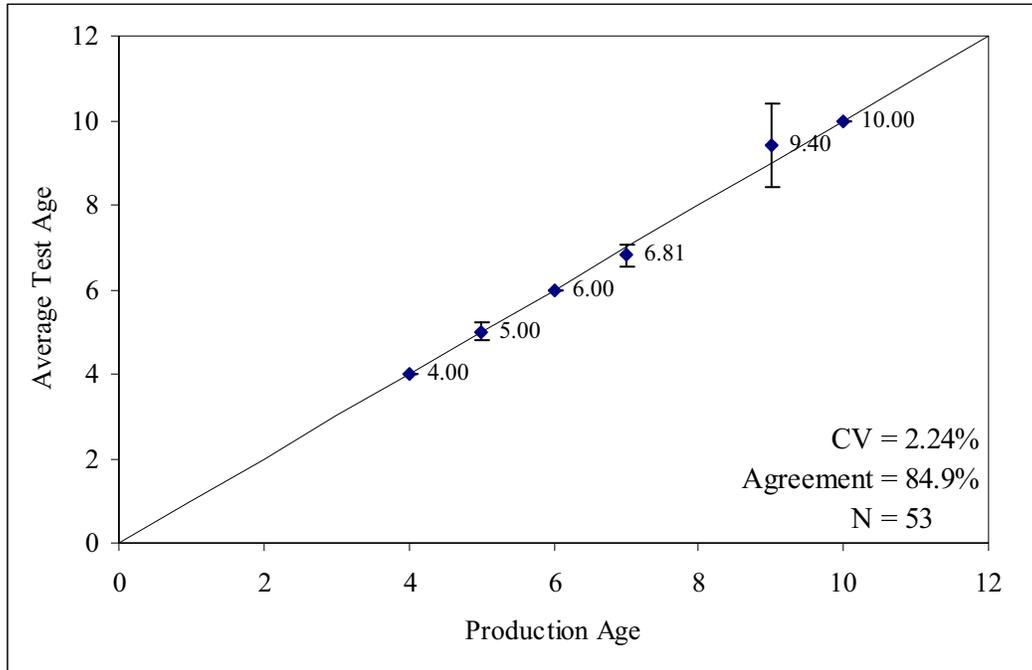


Figure 10. Results of haddock age-reader precision exercise against randomly selected samples from the 2005 NEFSC commercial port samples (2nd quarter). (A) Age-bias plot, showing the average age attained during the exercise for fish of each age as determined during production aging. Error bars indicate 95% confidence intervals. (B) Age-frequency table, showing the ages attained during the test exercise across the top and the production ages on the left. Numbers in the shaded boxes indicate agreement between the two ages. Numbers above this diagonal indicate fish which were over-aged during the exercise; those below the shaded boxes were under-aged during the exercise. Total age frequencies are given by age for both the test and production ages.

A.



B.

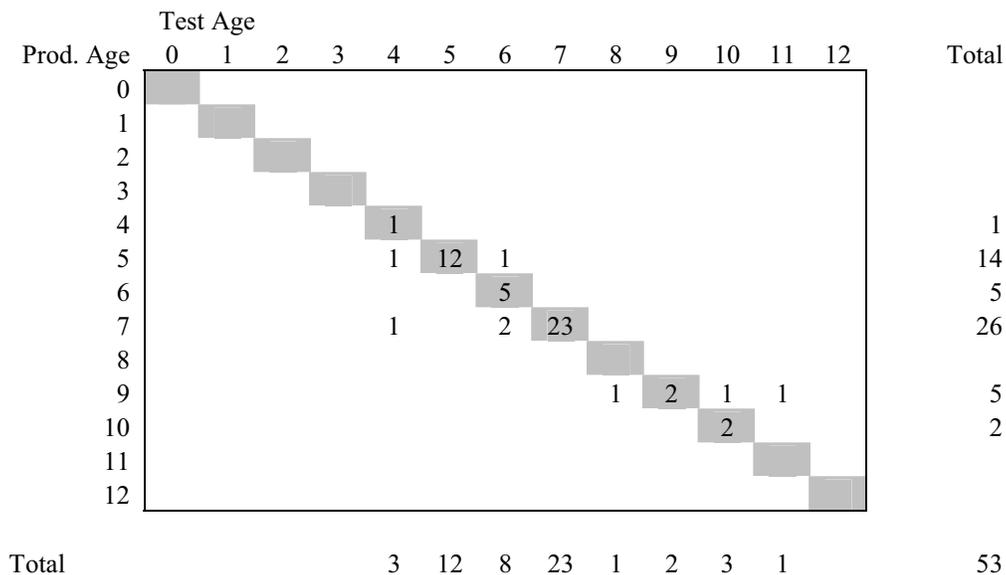
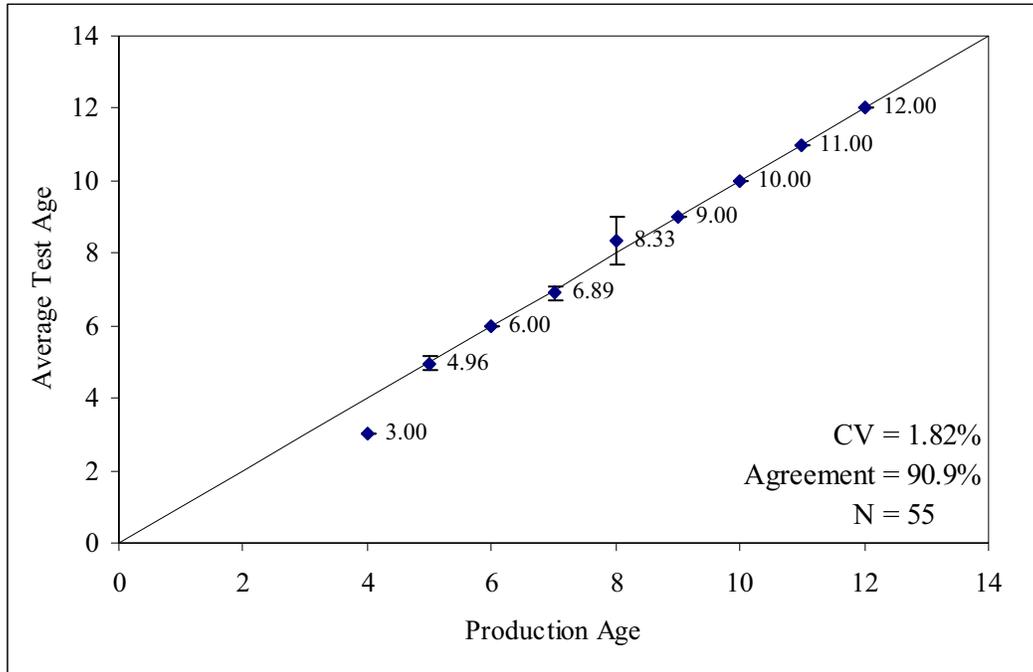


Figure 11. Results of haddock age-reader precision exercise against randomly selected samples from the 2005 NEFSC commercial port samples (3rd quarter). (A) Age-bias plot, showing the average age attained during the exercise for fish of each age as determined during production aging. Error bars indicate 95% confidence intervals. (B) Age-frequency table, showing the ages attained during the test exercise across the top and the production ages on the left. Numbers in the shaded boxes indicate agreement between the two ages. Numbers above this diagonal indicate fish which were over-aged during the exercise; those below the shaded boxes were under-aged during the exercise. Total age frequencies are given by age for both the test and production ages.

A.



B.

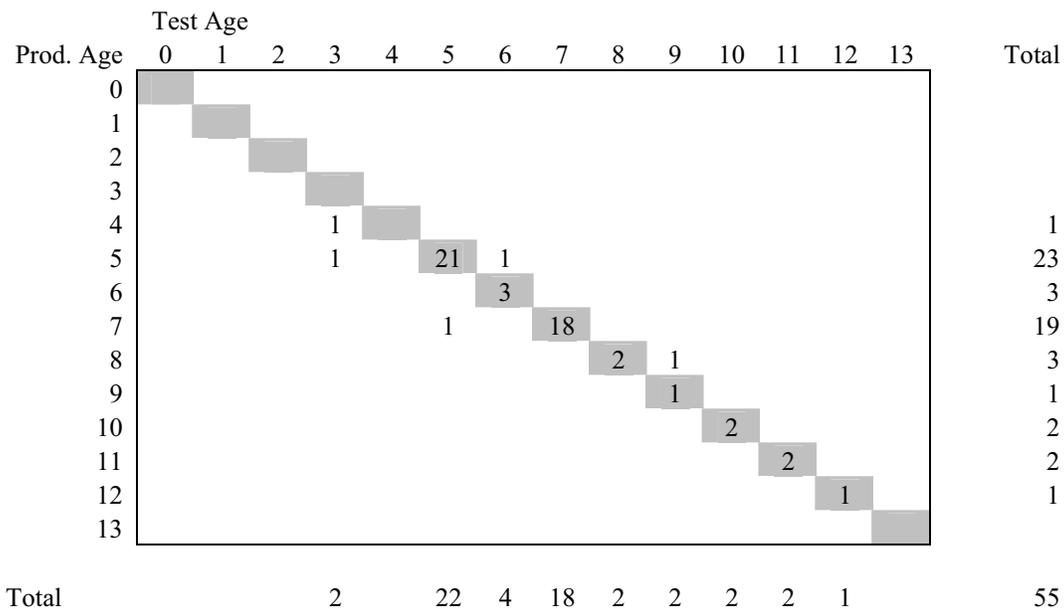
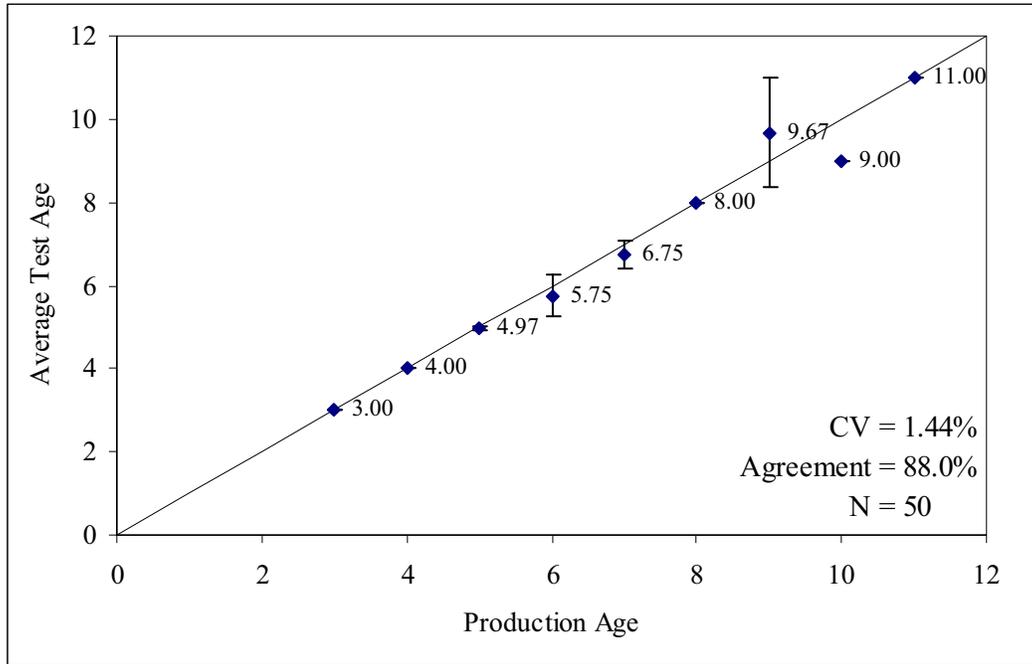


Figure 12. Results of haddock age-reader precision exercise against randomly selected samples from the 2005 NEFSC commercial port samples (4th quarter). (A) Age-bias plot, showing the average age attained during the exercise for fish of each age as determined during production aging. Error bars indicate 95% confidence intervals. (B) Age-frequency table, showing the ages attained during the test exercise across the top and the production ages on the left. Numbers in the shaded boxes indicate agreement between the two ages. Numbers above this diagonal indicate fish which were over-aged during the exercise; those below the shaded boxes were under-aged during the exercise. Total age frequencies are given by age for both the test and production ages.

A.



B.

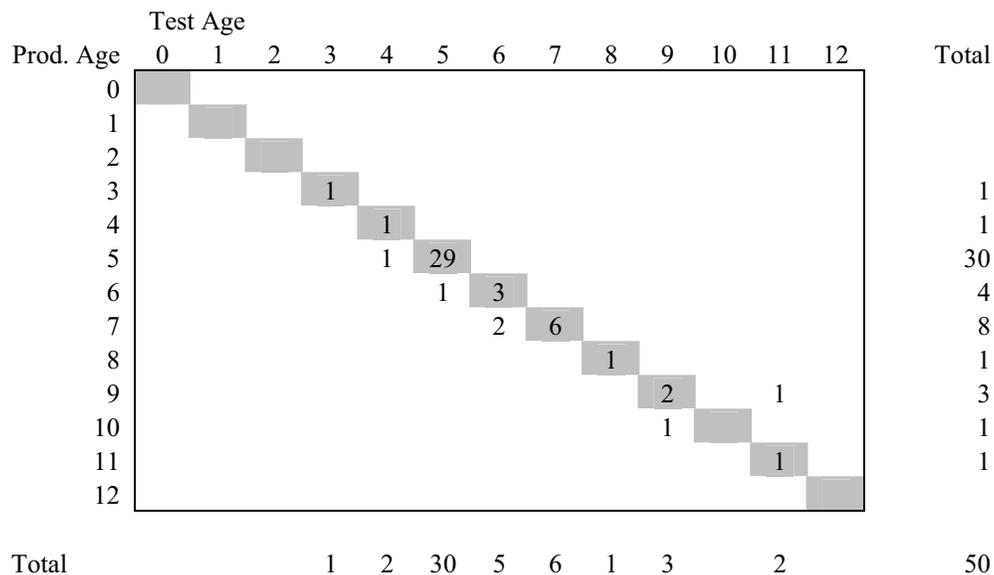
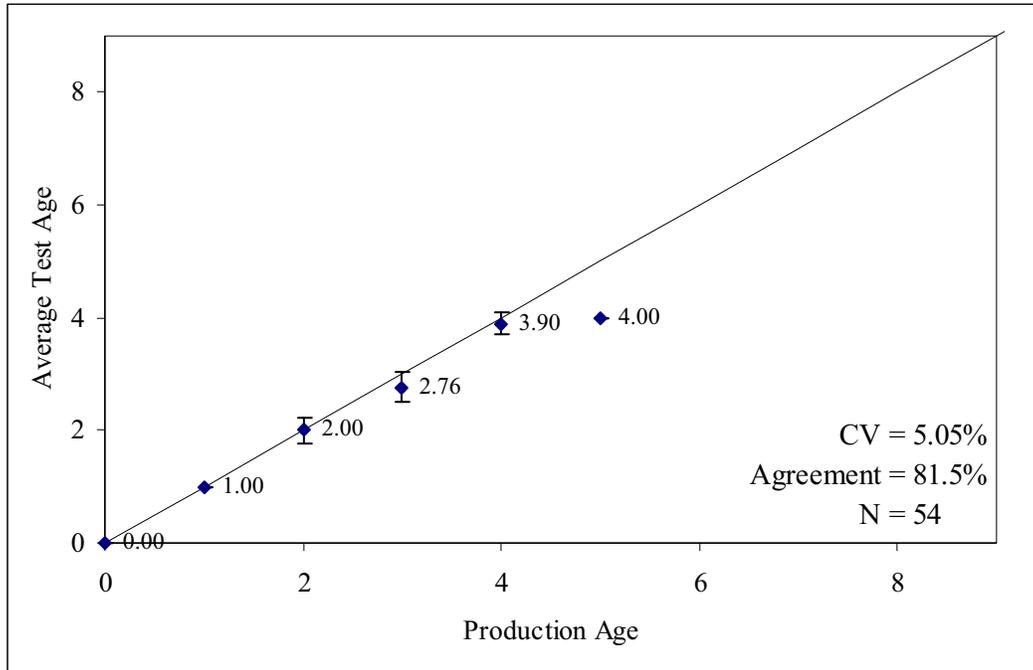


Figure 13. Results of yellowtail flounder age-reader precision exercise against randomly selected samples from the 2005 NEFSC autumn bottom trawl survey. (A) Age-bias plot, showing the average age attained during the exercise for fish of each age as determined during production aging. Error bars indicate 95% confidence intervals. (B) Age-frequency table, showing the ages attained during the test exercise across the top and the production ages on the left. Numbers in the shaded boxes indicate agreement between the two ages. Numbers above this diagonal indicate fish which were over-aged during the exercise; those below the shaded boxes were under-aged during the exercise. Total age frequencies are given by age for both the test and production ages.

A.

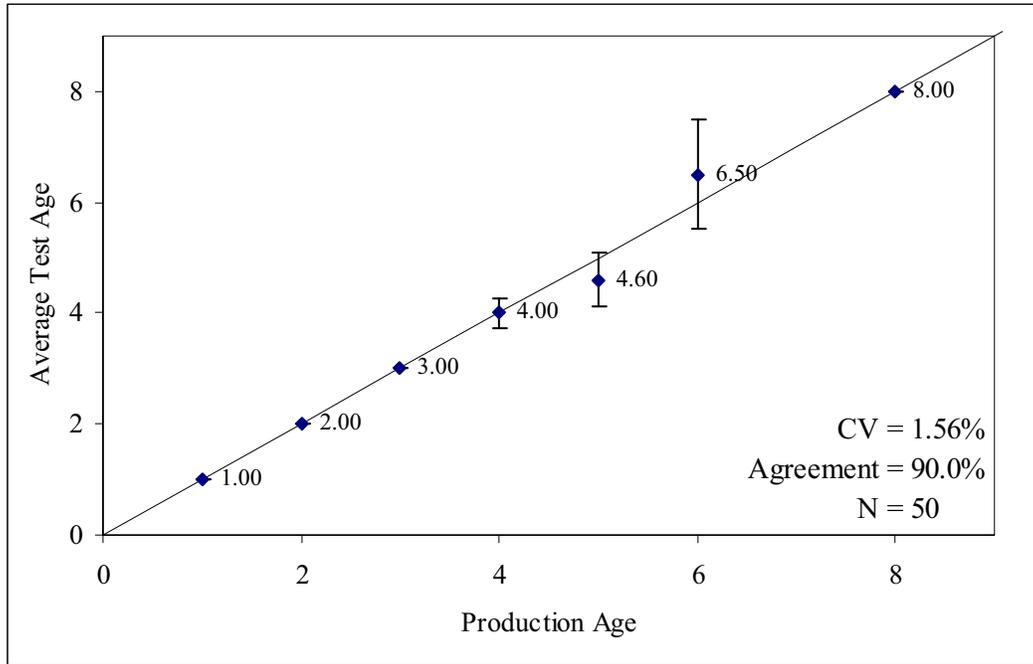


B.

Prod. Age	Test Age							Total
	0	1	2	3	4	5	6	
0	4							4
1		9						9
2		1	11	1				13
3			5	11	1			17
4				1	9			10
5					1			1
6								
Total	4	10	16	13	11			54

Figure 14. Results of yellowtail flounder age-reader precision exercise against randomly selected samples from the 2006 NEFSC spring bottom trawl survey. (A) Age-bias plot, showing the average age attained during the exercise for fish of each age as determined during production aging. Error bars indicate 95% confidence intervals. (B) Age-frequency table, showing the ages attained during the test exercise across the top and the production ages on the left. Numbers in the shaded boxes indicate agreement between the two ages. Numbers above this diagonal indicate fish which were over-aged during the exercise; those below the shaded boxes were under-aged during the exercise. Total age frequencies are given by age for both the test and production ages.

A.



B.

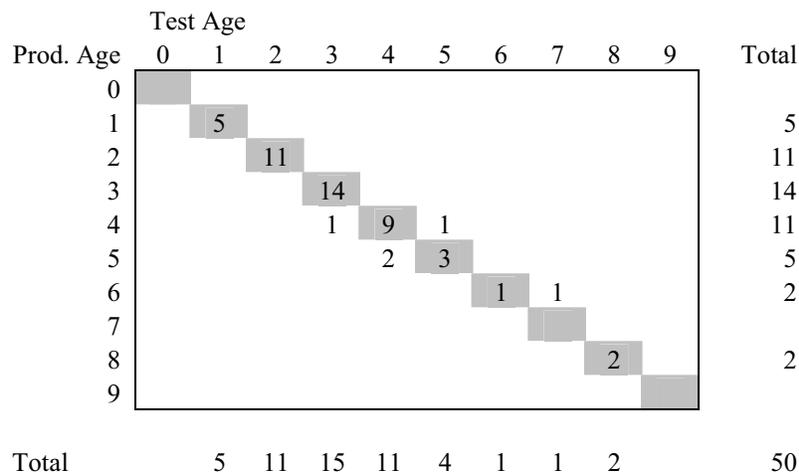
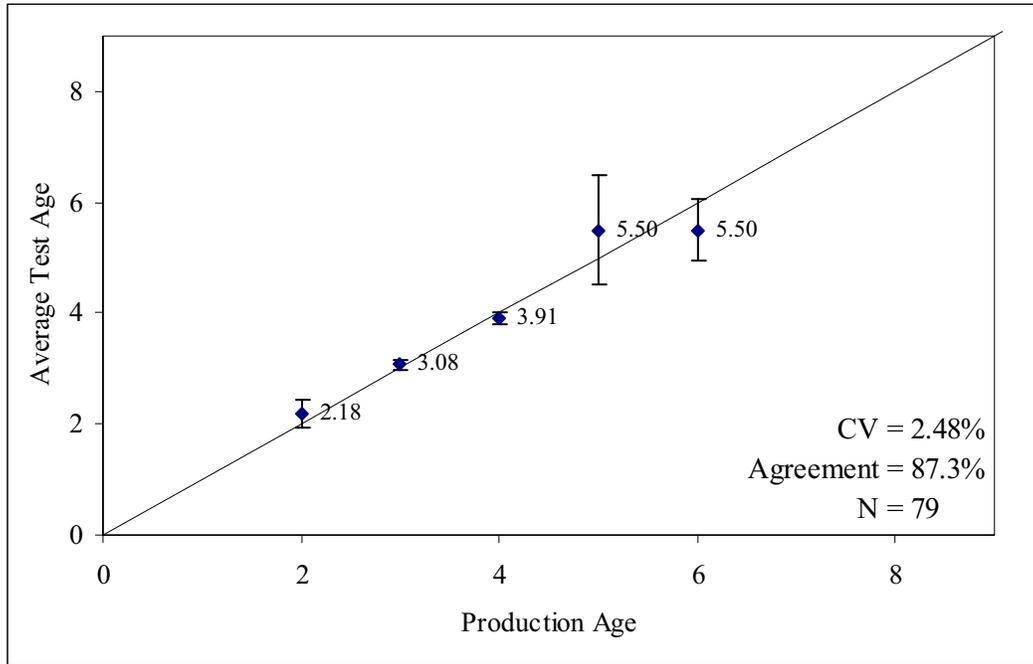


Figure 15. Results of yellowtail flounder age-reader precision exercise against randomly selected samples from the 2005 NEFSC commercial port samples (all quarters). (A) Age-bias plot, showing the average age attained during the exercise for fish of each age as determined during production aging. Error bars indicate 95% confidence intervals. (B) Age-frequency table, showing the ages attained during the test exercise across the top and the production ages on the left. Numbers in the shaded boxes indicate agreement between the two ages. Numbers above this diagonal indicate fish which were over-aged during the exercise; those below the shaded boxes were under-aged during the exercise. Total age frequencies are given by age for both the test and production ages.

A.



B.

Prod. Age	Test Age								Total
	0	1	2	3	4	5	6	7	
0	1								1
1		1							1
2			9	2					11
3				37	3				40
4				2	20				22
5						1	1		2
6						2	2		4
7								1	1
Total			9	41	23	3	3		79

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